A Recommended Study Area for the CINMS Management Planning Process:

Ecological Linkages in the Marine Ecology from Point Sal to Point Mugu, including the Marine Sanctuary

by

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REPORT OVERVIEW

The purpose of this report is to assist the management of the Channel Islands National Marine Sanctuary (CINMS) in identifying a study area for the Draft Environmental Impact Statement (DEIS) and the CINMS Management Plan. The management of the CINMS is considering four alternative study areas for the DEIS: 1) existing CINMS boundaries, 2) from Point Mugu to Cambria (southern boundary of Monterey Bay National Marine Sanctuary), 3) from Point Mugu to Point Sal, and 4) from Point Mugu to Point Conception.

In order to assist the management of CINMS, this report:

- reviews information on the linkages in the marine environment from Cambria to Point Mugu, including the CINMS;
- describes the approach used to make the recommendation; and
- characterizes the recommended study area from Point Mugu to Point Sal.

Approach

The study area for the DEIS and the CINMS Management Plan must conform to the priority management goal of the National Marine Sanctuary Program. In accordance to the CINMS Management Plan (1983), the *priority* sanctuary management goal is to "maintain, restore, and enhance living resources by providing places for species that depend on marine areas to survive and propagate".[1] Given this priority management goal, the recommended study should encompass the ecological linkages that are needed to protect the marine sanctuary.

A review of information on ecological linkages

Sanctuary managers and planners cannot depend only on scientific information to define a study area (consistent with Shrader-Frechette and McCoy 1994; Scheiber 1995; NRC 1999;Agardy 1999). The choice for the four alternatives study areas was not only based on scientific information but on public values and interests as well.

This report describes information on the ecological linkages in the marine ecology from Cambria to Point Mugu, including the CINMS. In addition, a section of this report describes scientific information that shows large-scale changes in primary and secondary productivity throughout the SCB between 1951 and 1993 (McGowan et al. 1998). Large-scale biological changes in the marine environment are due to climatic variations in the atmosphere and changes in the oceanographic conditions. These climatic and oceanographic variations have resulted in changes to biogeographical ranges and spatial patterns of marine species and in community structure.

The systems of the Southern California Bight, a marine system in an area between Point Sal (in central California) and *Punta Banda* (south of Ensenada, *Baja* California, Mexico) (Dailey et al. 1993). The Southern California Bight includes the Channel Islands and the marine sanctuary. The CINMS depends on relationships between circulating water masses and currents, various geochemical processes, oceanographic processes, microorganisms, phytoplankton, zooplankton, fishes, a rich flora of benthic macroalgae and seagrasses, benthic invertebrates, the distribution and abundance of nutrients and other organisms.

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[1] National Marine Sanctuary Act 16 U.S.C. 1431 ET. SEQ., Sec. 301(b)(5)(9),

Studies show that the marine species and habitats of the CINMS are "linked" to larger-scale oceanographic, atmospheric and biogeographic conditions. The marine sanctuary is linked to the ecological processes of the Southern California Bight. Large-scale biological changes in the marine sanctuary are caused by changes in the atmosphere, climatic events, such as El Niño, and the oceanography of the SCB (Chelton et al. 1992).

The recommended study area

Given the alternative study areas, the report recommends the study area between Point Sal and Point Mugu. This recommendation is my own; it does not necessarily reflect the views of any organization. The recommendation is based on my interpretation of the scientific information gathered during a six week period, and interviews with a number of marine scientists who study the area.

Alternative #3, from Point Mugu to Point Sal, is recommended for the following reasons:

- The marine are to Point Sal should be considered part of the study area because marine scientists show that this area influences species distribution and abundance (Horn and Allen 1978; Murray et al. 1980; Littler 1980; Murray and Littler 1981, 1984, 1989; Littler et al. 1991; Barry et al. 1995; Roy et al. 1996; Burton 1998; Sagarin et al. 1999).
- There is a paucity of information on the marine area north of Point Sal (Milton Love, *personal communication*). So, Alternative #4, from Point Mugu to Cambria, was not recommended because of the lack of scientific information to support this study area. Alternative #4 would capture more of the colder water mass and California Current (consistent with Harms and Winant 1998; Love et al. 1999).
- Information from studies of coastal mainland ecosystems (e.g., coastal wetlands) and processes support a recommendation that includes the coastal mainland areas between Point Mugu to Point Sal (Zedler 1984, 1987, 1996; California State Lands Commission 1994; Ferren et al. 1995; California Coastal Conservancy 1997; Saiki 1997; US Air Force 1997).
- The Santa Barbara Channel should be included in the study area because it includes two biogeographical provinces, the cold water of the Oregonian Province and the warmer water mass of the Californian Province, and a transition zone between the two water masses (Horn and Allen 1978; Murray et al. 1980; Littler 1980; Murray and Littler 1981, 1984, 1989; Littler et al. 1991; Murray and Bray 1993).
- Abiotic and biotic factors associated with eddies in the SB Channel influence the distribution, recruitment and survival of pelagic juvenile fishes and other marine organisms found in and around the marine sanctuary (Hickey 1993; Henderschott and Winant 1997; Harms and Winant 1998; Nishimoto 1999; Nishimoto and Washburn, under review).
- Nearshore waters along the coastal mainland and the Channel Islands include habitats are used by a number of marine species found in the marine sanctuary (Murray and Bray 1993; Cross and Allen 1993).

The pieces must stick within their pattern or the whole thing collapses and the design is gone. We wonder whether in the present pattern the pieces are not straining to fall out of line; whether the paradoxes of our times are not finally mounting to a conclusion of ridiculousness that will make the whole structure collapse.

-John Steinbeck, <u>The Log from the Sea of Cortez.</u> New York: Penguin Books. 1979, p. 46.

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I. Introduction

> The National Marine Sanctuary Program expands our nation's long history of protecting special areas on land to embrace the seas. It brings an ecosystem approach to marine environmental protection and asks us to adopt a new ethic of marine stewardship, but perhaps most of all, it challenges us to work together to find creative solutions to the problems facing our oceans and coasts.[2]

The objective of this report is to make a recommendation for a study area that can support the priority management goal for the National Marine Sanctuaries Program. In accordance to the National Marine Sanctuary Act, the priority goal of marine sanctuary management is to "maintain, restore, enhance, living resources by providing places for species that depend on marine areas to survive and propagate" (The National Marine Sanctuary Act 16 U.S.C. 1431 <u>ET. SEQ</u>., Sec. 301(b)(5)(9)). The priority management goal of the CINMS management is to "protect marine resources and the environment" (CINMS Management Plan 1983).[3] Marine ecosystem protection is also described in the first report of the new Marine Sanctuaries Conservation Series (NOAA 1999):

> By definition, ecosystem management should protect and restore ecological components, functions and structures according to socially defined values and scientific information, in an integrated, holistic manner.

The protection of marine biodiversity and ecosystem function, processes and structures requires an understanding of the ecological linkages of the marine environment (Gunderson et al. 1995; Costanza et al. 1998; NRC 1999 among others).[4]

1. The Alternative Study Areas

CINMS management is currently revising the Management Plan (1983). Based on "scoping hearings" held during the summer of 1999, CINMS management is considering four alternative study areas. Identification of a study area is needed to complete a Draft Environmental Impact Statement (DEIS), a document that is required by the National Environmental Protection Act of 1970, as amended (PL 91-190, 42 U.S.C. Sections 4321-4347).

This report briefly summarizes ecological linkages described by marine scientists who study the marine sanctuary and, more generally, the biology, ecology, climate, biogeography, and oceanography of SCB. CINMS management will use this review to determine the study area for the DEIS.

CINMS management is considering four alternative study areas for the DEIS and the CINMS Management Plan: 1) existing CINMS boundaries, 2) from Point Mugu to Cambria (southern

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[2] http://www.sanctuaries.nos.noaa.gov/natprogram/natprogram.html

[3] A discussion of the current sanctuary boundary with respect to the management goal of protection is found in Hierta (1993).

[4] The priority of marine ecosystem protection is supported by scientists (National Research Council 1999), other federal agencies (Gore 1993; Corn 1993; US Department of the Interior 1994, 1995; White House Office of Environmental Policy 1994; US Department of Defense 1994; US General Accounting Office 1994), and local governments (Haeuber 1996).

boundary of Monterey Bay National Marine Sanctuary), 3) from Point Mugu to Point Sal, and 4) from Point Mugu to Point Conception.

Each alternative study area reflects an alternative ecological scale. Ecological scale can be expressed along many dimensions. Many ecological processes display what is termed a "characteristic scale" which is defined as the level of spatial resolution or spatial extent that best captures their defining characteristics. (Note some scientists argue that overemphasis on particular scales of phenomena results in neglect of their sub- and supra-level ecological dimensions.)

Marine scientists who reviewed a draft of this report noted that the four alternative study areas do not include all of the important physical and biological scales affecting the CINMS. One marine scientists who reviewed an earlier draft of this report noted that the inclusion of the southern Channel Islands, including Santa Barbara Island (which is in the sanctuary), as well as San Nicholas, Santa Catalina, and San Clemente Islands should also be included in the analysis. All eight Channel Islands, including the southern Channel Islands are an integral part of the SCB oceanographic regime. The decision to exclude three southern Channel Islands is an administrative decision that is not supported by scientific information.

A second reviewer noted that populations located further south than Point Mugu contribute to local populations. For example, southern source populations occur for many commercially important fishes, including giant sea bass, white sea bass, kelp bass, sheephead, and yellowtail jacks. This reviewer also noted that the alternative study areas are arbitrary and do not reflect the ecology of the SCB.

The ideal study area for the DEIS should (1) encompass those ecological processes and relationships that are needed to protect the ecosystems of the marine sanctuary, and (2) support the priority management goal to protect the sanctuary's marine ecosystems, as specified in the National Marine Sanctuary Act.

2. Ecological Linkages

There are ecological linkages that include, for example, the largest concentration of blue whales in world to upwelling conditions of the Southern California Bight (SCB), and the appearance of krill offshore the northern Channel Islands.[5] There are many other examples: the linkage between the endangered Brown Pelican, the habitats used by the pelican in the marine sanctuary, and the fishes consumed by the pelican that exist in mainland coastal ecosystems and the nearshore environment (Jaques et al. 1996).

Another example is the linkage between the Santa Barbara Channel eddy, the presence of juvenile rockfish in the eddy, and an El Niño event is another example (Nishimoto and Washburn, under review).

These are examples of dramatic ecological linkages that exist between marine species of the sanctuary, the SB Channel, and the coastal mainland. The biology, oceanography and atmospheric conditions of marine systems are linked and connected to one another. The boundary between the marine and coastal ecosystem is not as clear as we might assume.

3. Scientific Uncertainty

[5] This linkage is being studied by Dr. J. Calambokidis.

Sanctuary managers and planners cannot depend only on scientific information to define a study area (consistent with Ludwig et al. 1993; Shrader-Frechette and McCoy 1994; Scheiber 1995; NRC 1999; Hourigan 1999; Agardy 1999).

There are many ecological linkages that are subtle and difficult to identify and understand. The identification of ecological linkages is not a "black and white" exercise. The spatio-temporal scale of dynamic and complex marine systems is difficult for human beings to predict (Mann and Lazier 1996; Steele 1974; 1998). Hydrographic circulation patterns and climate events, such as El Niño, span scales of up to thousands of kilometers. In addition, the dispersal and migration of organisms can span huge geographical distances, such as the migration of gray whales, the flight of the arctic tern, and the return of the wild King salmon to mainland watersheds. The large range of spatial and temporal features of marine systems make it difficult to predict and understand ecological relationships and linkages.

Indeed, marine scientists recognize that the linkages that exist between systems and the "boundaries" of marine ecosystems are difficult to scientifically determine (Steele 1974, 1985, 1998; Agardy 1999; Hourigan 1999; Agardy 1999; Costanza et al. 1998; NRC 1999). In terrestrial ecosystems, the focus of environmental managers and planners is on one or more species of concern over a defined geographic area, such as a watershed (Lackey 1998). For example, we manage a particular fish species in a certain lake. The lake and its watershed are the unit of concern. The decision on the "unit of concern" defines the management concern. In other words, administrative jurisdiction and responsibility begins with identifying a terrestrial area, e.g., special habitat of concern.

Sanctuaries and other marine protected areas have different management concerns than terrestrial systems (Steele 1974). The greatest single factor underlying the difference between terrestrial and marine systems is the nebulous nature of "boundaries" in the fluid environment of the sea. Agardy (1999: 52) agrees and writes:

> It is notoriously difficult to attach boundary conditions to marine ecological processes, just as it is difficult to bound the impacts that affect these processes. In essence, it is impossible to "fence in" living marine resources or the critical ecological processes that support them, just as it is impossible to "fence out" the degradation of ocean environments caused by land-based sources of pollution, changes in hydrology, or ecological disruptions occurring in areas adjacent or linked to a protected area.

There are many reasons for the lack of scientific information on large-scale ecosystem relationships and linkages:

- There exists a mismatch between scales of atmospheric and oceanographic processes and the spatial and temporal dimensions of biological studies and research (McGowan et al. 1998). As McGowan, Cayan and Dorman (1998: 210) write in their published article in *Science*, "Much of the biological, observational evidence is disconnected spatially and often discontinuous temporally ... we must accept less than ideal data in our attempt to understand what is happening."
- In general, studies do not link information on oceanographic regimes with information on habitat distribution and marine biodiversity.
- In general, studies do not show how larger-scale conditions affect the general health of the local populations and marine habitats (e.g., Palmer et al. 1996).

- In general, studies do not link large-scale anomalies, such as El Ni–o events, to the ecology of coastal systems (Lough 1994; Holbrook and Schmitt 1996).
- Hydrographic circulation patterns and episodic events can span thousands of kilometers, so the biological processes that are affected by these patterns and events exhibit large-scale components (Allison et al. 1998 among others). These components and linkages are difficult to determine due to their spatial and temporal scale. The hydrography in the Santa Barbara Channel, for example, varies from one year to another (Harms and Winant 1998).
- There are few long-term and interdisciplinary studies of marine ecosystems. Marine scientists tend to focus on the distribution and abundance of marine species and habitats.

In summary, there exists a paucity of scientific information on the ecological linkages in the marine environment of the CINMS. Local changes in a marine population can occur in accordance to large-scale changes in oceanographic and atmospheric conditions (Palmer et al. 1996). For example, El Nino events have led to a decline in southern California kelp forests and certain species of fishes in the marine sanctuary. The destruction of southern California wetlands has led to a decline in fish and bird abundance. Human activities also influence the relationship between marine species and habitats. In southern California, El Nino storms increased the flow of creeks and rivers. These same storms increased the amount of water pollution from point and nonpoint sources entering the marine system.

4. Approach

Based on the priority management goal of National Marine Sanctuaries Program, the study area for the DEIS should encompass the systems needed to sustain the health or well-being of the organisms, habitats and ecosystems of the marine sanctuary.

An *ideal* study area should encompass those ecological processes and relationships that are needed to protect the ecological systems of the marine sanctuary, as specified in the National Marine Sanctuary Act.

5. An Introduction to the Recommendation

An *ideal* study area would be the entire SCB. Scientists have recognized the uniqueness of the SCB as a system of dynamic relationships that influence the ecology of the marine sanctuary (Dailey et al. 1993 among others). However, the entire SCB is not an alternative study area identified by CINMS management.

Given the alternatives, the marine and coastal area from Point Sal to Point Mugu is recommended because the following factors have or can have a direct impact on the CINMS:

- The marine area north of Point Conception should be considered part of the study area due to the shift in local and regional species composition that can occur during increases or decreases in sea surface temperature and climate perturbation.
- Information on field observations and studies of the abundance of fishes, birds, marine mammals and coastal ecosystems on Vandenberg Air Force Base and the Mugu Lagoon supports the recommendation for the study area to the coastal mainland areas between Point Mugu to Point Sal. The decision to go further north of Point Sal would capture more of the colder water of the Oregonian province and water mass which San Miguel Island is a part of.
- The SB Channel should be included in the study area because it is a representation of two marine biogeographical provinces, the cool Oregonian Province and the warm Californian Province, and the transition zone between the two regimes.

- Abiotic and biotic factors associated with eddies in the SB Channel may be important in the distribution, recruitment and survival of pelagic juvenile fishes and other marine organisms.
- Nearshore waters along the mainland coast include the presence of habitats that are used by a number of marine species of the sanctuary. In addition, the coastal mainland ecosystems provide nutrients (and pollutants) to the marine environment of the sanctuary.

A characterization of these factors is the focus of the remainder of this report.

II. The Link between the CINMS and the Southern California Bight

The Channel Islands are distributed along the edge of the continental borderland of the SCB.[6] The SCB is commonly delineated as a system that extends from offshore Point Sal (in central California) to *Punta Banda* (south of Ensenada, *Baja* California, Mexico).[7]

The mean circulation in the SCB is dominated by the poleward-flowing Southern California Countercurrent. The California Current, which is fed by the West Wind Drift, is the eastern limb of the North Pacific gyre. This current turns shoreward near the southern US border, and a branch of the current turns poleward into the SCB, where it is known as the Southern California Countercurrent. The Southern California Countercurrent flows equatorward along the west coast of the US throughout the year. This countercurrent is strongest in summer and winter. This counter current draws warmer water from the south and forces the water northwest through the Channel Islands.

The confluence of the California Current and the Southern California Countercurrent has been shown to affect the abundance and distribution of marine species (Dailey et al. 1993). The systems of the SCB, including the Channel Islands and the marine sanctuary, depend on relationships between circulating water masses and currents, various geochemical processes, oceanographic processes, microorganisms, phytoplankton, zooplankton, fishes, a rich flora of benthic macroalgae and seagrasses, benthic invertebrates, the distribution and abundance of nutrients and other organisms.

Marine scientists show that the SCB provides essential nutrients and marine habitats for a range of species and organisms of the marine sanctuary. Submarine canyons, ridges, basins and seamounts provide unique deep habitats within the SB Channel. The basins provide habitats for a significant number of mid-water and benthic deep sea fishes near the coast, including the Channel Islands (Dailey et al. 1993: Chapter One). Nearshore waters provide a variety of other habitats. Soft substrates, such as those in bays and estuaries and exposed sandy beaches, shelves, and slopes, are abundant along the Islands. Hard substrates, such as the rocky intertidal, shallow subtidal reefs, deep rock reefs, and kelp beds are abundant around the Islands as well. Kelp beds form an unique shallow water community and provides a haven for a complex array of algal species, invertebrates, fishes and marine mammals. Shallow subtidal and intertidal areas form

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[6] The length of coast is roughly the same on the Channel Islands (530 km) and on the mainland between Point Conception and the Mexican Border (490 km). About 70% of all rocky shores occur on the islands and about 70% of all sandy beaches occur on the mainland (Thompson et al. 1993).
[7] Comprehensive surveys of the scientific literature on the physical oceanography of the SCB are provided by Harms and Winant (1998), Hickey (1992, 1993), and Brink and Muench (1986). A characterization of the ecology of the SCB is found in Dailey et al. (1993).

habitats for marine organisms, such as benthic marine invertebrates.

The Dynamic SCB

Members of the California Cooperative Oceanic Fisheries Investigations (CalCOFI) have studied the SCB since 1950 (Hickey 1993; Scheiber 1995). CalCOFI information provides an up-to-date characterization of the dynamic currents and water properties of the SCB. In addition, this information is also used to characterize trends in the ecology of the SCB.

CalCOFI studies show that circulation within the SCB is highly variable in time and space, and is determined by the relative strengths of wind stress and oceanographic pressure gradients through the Santa Barbara Channel (SB Channel). The abundance and distribution of marine species in the marine sanctuary is affected by the oceanography of the SCB.

1. El Niño, La Niña, and ENSO

El Niño (EN) is characterized by a large scale weakening of the trade winds and warming of the surface layers in the eastern and central equatorial Pacific Ocean. El Niño events occur irregularly at intervals of 2-7 years, although the average is about once every 3-4 years. They typically last 12-18 months, and are accompanied by swings in the Southern Oscillation (SO), an interannual see-saw in tropical sea level pressure between the eastern and western hemispheres. During El Niño, unusually high atmospheric sea level pressures develop in the western tropical Pacific and Indian Ocean regions, and unusually low sea level pressures develop in the southeastern tropical Pacific. SO tendencies for unusually low pressures west of the date line and high pressures east of the date line have also been linked to periods of anomalously cold equatorial Pacific sea surface temperatures (SSTs) sometimes referred to as La Niña.

The Southern Oscillation Index (SOI), defined as the normalized difference in surface pressure between Tahiti, French Polynesia and Darwin, Australia is a measure of the strength of the trade winds, which have a component of flow from regions of high to low pressure. High SOI (large pressure difference) is associated with stronger than normal trade winds and La Niña conditions, and low SOI (smaller pressure difference) is associated with weaker than normal trade winds and El Niño conditions. The terms ENSO and ENSO cycle are used to describe the full range of variability observed in the Southern Oscillation Index, including both El Niño and La Niña events.

El Niño Southern Oscillation (ENSO) events have had dramatic effects on the flow patterns of the SCB (Chelton et al. 1992). Changes in the flow patterns have been shown to have a number of biological impacts:

- population shifts in commercially harvested species, such as squid, rockfish and lobster;
- transport of enormous volumes of sediments and suspended materials from the mainland to coastal and offshore waters;
- disturbance to critical marine habitats, notably storm and water temperature damage to kelp forests.

CalCOFI investigators and other marine scientists show that large-scale changes, or what is referred to as a *regime shift*, in the physical and biological processes can lead to change in the distribution and abundance of some marine species. Each regime shift changes the basic nature of marine ecology for several decades at a time (or on the order of several human generations). McGowan et al. (1998) state that the last regime shift occurred in 1977.

Based on an analysis of CalCOFI data,[8] Roemmich and McGowan (1995a, b) document large-scale changes in primary and secondary productivity throughout the SCB between 1951 and 1993. Hayward et al. (1996) and McGowan et al. (1998) show that large-scale biological responses in the marine environment due to climatic variations in the atmosphere has resulted in changes in geographical ranges and spatial patterns of species and in community structure. This evidence suggests that the maintenance of community structure and patterns of native species diversity has changed in accordance to hydrographic perturbations and climate-ocean variability.

A summary of the changes described by marine scientists is below:[9]

- The Euphotic Zone (upper sunlight zone of the sea, less than 120 m thick): Smith and Kaufmann (1994) show a long-term deficit in the supply of food necessary to meet the metabolic demands of the sediment community. The long-term increase in sea surface and upper water column temperatures and physical stratification in the system has resulted in a lower rate of supply of nutrients to the euphotic zone; a decrease in productivity and a general decline of zooplankton and other species (e.g., larval fish production, sea birds, kelp production and a shift in benthic, intertidal community structure.) Despite this decline in food supply, the food demand of the deep-benthic sea community remained constant.

- Macrozooplankton: Since the late 1970s, macrozooplankton volume in the California Current has declined over 70%, in concert with increasing sea surface temperatures (Roemmich and McGowan 1995a,b; McGowan et al. 1998). Reduced macrozooplankton has a major impact at higher trophic levels by changing the nature of the food supply.

- Fishes and Invertebrates: Dugan and Davis (1993) document the general decline in long-term productivity in 19 species of nearshore fishes and invertebrates in California from 1947 to 1986.

- Data from the California Department of Fish and Game (CDFG) show decreases in harvest for most categories of groundfish, California sea urchin landings, landings of swordfish and selected shark species, Pacific Mackerel, Pacific Herring, California halibut, market squid (for the period 1997-1998) among others (e.g., CalCOFI 1995, 1998).

- A study by Love et al. (1998) of long-term trends in the SCB commercial fishing vessel rockfish fishery shows a substantial decline from 1980 to 1996, with extremely low catches from 1993 to 1996.

- The estimated abundance in streams south of Point Conception of steelhead rainbow trout is probably on the order of a 100 - 300 adults (Pacific Fishery Management Council 1996).

- Southern Sea Otter: The southern sea otter population continues to decline (Bodkin et al. 1996; Estes et al. 1996).

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[8] CalCOFI has compiled several spatially and temporally comprehensive data sets for the SCB from strategically located offshore stations (Hickey 1993: 21-25).
[9] For further information on these changes, see "Identification and Synthesis of Biological and Physical Published Data on the Marine Environment from Cambria to Point Mugu, including the Northern Channel Islands" (McGinnis October 1999).

- Oceanic Birds: Ecological theory predicts that in a stable ecosystem those species occupying high trophic levels maintain native species diversity and community structure (Paine 1966). Upper trophic level animals such as pelagic birds are indicators of the health of the marine environment (Veit et al. 1996). Evidence suggests that the abundance of oceanic birds in the region and the SCB have declined steadily since 1988 (Veit et al. 1996, 1997). Veit et al. (1996) believe that this reduction reflects considerable biological change within the California Current System. Veit et al. (1996, 1997) indicate that ocean warming and climatic events change pelagic bird abundance within the California current system.

- Southern California Kelp: Starting in the late 1970s, Tegner et al. (1996, 1997), Tegner and Dayton (1991), and Dayton et al. (1992) show that kelp forests have suffered great damage. Tegner et al. (1997) show a two-thirds reduction in standing biomass since 1957 in southern California kelp forests.

- Global Climate Change: There is also some indication that the frequency of these climatic events may be increasing (McGowan et al. 1998).

In summary, changes in atmospheric and oceanographic conditions have been shown to decrease or increase marine species abundance and distribution in the marine sanctuary and the SCB.

III. Ecological Links

This section describes published scientific information on ecological links from Cambria to Point Mugu, including the northern Channel Islands and Santa Barbara Island (i.e., the CINMS).

1. Biogeographical Provinces and Faunal Regimes

Murray and Littler (1981) define five distinct biogeographical provinces in the SCB based on analyses of 21 sites. Murray and Littler (1981) show that the marine floras of the island sites proximal to the California Current (San Miguel and Santa Rosa Islands) had much greater affinities with macrophytes north of Point Conception than did the floras bathed principally by the Southern California Countercurrent or those of mixed waters.

The northern Channel Islands straddle two faunal provinces and respective oceanographic regimes (i.e., the warm and cold temperate) (Murray and Littler 1981). San Miguel lies in the colder waters of the Oregonian Province, while Anacapa and Santa Barbara Islands are embedded in the warmer Californian Province. The eastern side of Santa Rosa Island and Santa Cruz Island lie in the transition zone between the two provinces. The transition zone is described as a third biogeographical province that affects the ecosystems of the islands (Seapy and Littler 1980; Murray and Littler 1981; Murray and Bray 1993). The transition zone shifts position with time depending on the relative strengths of the causal processes.

Other studies of distribution patterns of species also support the presence of two primary faunal regimes. California fish fauna assemblages may be classified into two groups -- those associated with cold- and warm-water masses (Horn and Allen 1978). Earlier work by Fitch (1967) of Pleistocene fossil fishes in southern California supports the presence of these faunal regimes. Studies of the distribution patterns of shallow water benthic mollusks (Valentine (1966), rocky intertidal assemblages (Kanter 1980; Murray et al. 1980; Littler 1980), kelp-bed fishes off Santa Barbara (Ebeling et al. 1980), and sandy beaches of the region, including the mainland (Dugan et al. 1999) show distinct but interrelated biogeographical provinces.

Temperature of the water is described as playing a prominent role in determining faunal/floral distributions (Horn and Allen 1978). Hydrographic patterns affect the dispersal of organisms (and pollutants). For example, because most nearshore fishes, invertebrates, and macroalgae have planktonic phases in their life histories, the spatial and temporal variability of their recruitment is linked to physical oceanographic processes, such as currents, eddies and upwelling (Roughgarden et al. 1988).

In summary, three biogeographical provinces were described in this section:
- the colder Oregonian Province;
- the warmer Californian Province; and
- a third province, the transition zone between the two provinces.

Depending on the season, the Channel Islands and the marine sanctuary are embedded in one or more of these biogeographical provinces. The current sanctuary's boundaries does not represent the dynamic character of these three biogeographical provinces. The marine species of San Miguel Island, for example, are dependent on the colder water of the Oregonian Province. The spatio-temporal scale of the biogeographical provinces change in accordance to hydrographic conditions of the SCB and climate perturbation. At times, the eastern side of Santa Rosa Island and Santa Cruz Island lie in the transition zone between these two provinces. Rigid classification of these three biogeographical provinces is not recommended because such a classification inevitably de-emphasizes the complex and shifting interrelationships of these regimes (Horn and Allen 1978).

2. Transition Zones

A transition zone involves an active interaction between two or more systems across their respective boundaries, e.g., the biogeographical provinces associated with the cold- and warm-water masses. This interaction between provinces results in a transition zone that includes properties from both systems. It can also result in a high-level of marine species diversity. The transitionary character of marine systems shapes the adaptive nature or, in more general terms, the *autopoietic*[10] character of ecosystems and species.

The Southern California Bight

[10] Living systems belong to the class of autopoietic systems. Autopoietic systems are "self-producing" systems. The system itself (limited by its boundary) is such that by the existence of itself (its structures, processes, etc.) it produces itself. The boundary of such a system is a structural manifestation of the system's underlying organization. A cell as a system renews its macromolecular components thousands of times during its lifetime. It maintains its identity and distinctiveness despite this turnover. This lasting unity and wholeness is called "autopoiesis". For a discussion of autopoiesis, see F.G. Varela, H.R. Maturana, and R. Uribe. 1974. Autopoiesis: The Organization of Living Systems, its Character and a Model. BioSystems 5: 187-196. With respect to environmental management and autopoiesis, see M. Hollick. 1993. Self-Organizing Systems and Environmental Management. Environmental Management 17, 5: 621-628.

As described earlier, the SCB is a complex transition zone between cold and warm temperate biotas (Murray and Littler 1981).[11] Marine scientists provide evidence for the transitional nature of the *entire* SCB using quantitative analyses of compositions of insular and mainland intertidal floras, which appear to show affinities of both warm- and cold- temperate biotas (Thom 1980; Murray and Littler 1981).

The Santa Barbara Channel

The SB Channel includes patterns of warm, saline water from the Southern California Countercurrent and the colder water from the California Current. Upwelling often occurs where these water masses meet, near the massive headlands of Point Arguello and Point Conception, as well as along much of the California coast, depending on the season. Upwelling plumes expand southward from headlands and frequently enter the SB Channel on the southern side of the western mouth (Atkinson et al. 1986). There can be a channelwide response to upwelling north of Point Conception (Auad et al. 1998). Oceanographic thermal fronts are abundant in the SB Channel and form as a consequence of upwelling and of current shear between the two primary currents (Harms and Winant 1998).

The extent to which cold water enters the SB Channel is variable (Harms and Winant 1998). In general, while the north shores of San Miguel and Santa Rosa Islands are embedded in the cold-water mass, the north shore of the Santa Cruz Island oscillates between cold-water and warm-water masses. If upwelling is intense, cold-water can reach the north side of Santa Cruz Island and will intrude into the island pass between Santa Rosa and Santa Cruz Islands.

Moreover, the SB Channel includes mesoscale eddies that are important to the general health of particular species and organisms in the region. The changing character of the SB Channel eddy, for example, and its potential role in enhancing survivorship of fishes during El Niño events has been observed (Nishimoto and Washburn, under review). Nishimoto and Washburn (under review: 8) propose that persistent cyclonic eddies in the SB Channel are "important local mechanisms for offsetting large-scale declines in marine populations associated with climate variations."

The importance of the SB Channel as a transition zone is linked to spatial and temporal variability observed in fish assemblages within habitats of the marine environment. Cross and Allen (1993) review the ecology of fishes in the major habitats of the SCB.

Schroeder (1999) provides preliminary evidence that the large amount of spatial and temporal variability observed in fish assemblages within habitats is primarily associated with the SB Channel's dynamic oceanography. In addition, recently published evidence (Nishimoto 1999) suggests that mesoscale spatial distributional patterns of pelagic juvenile fishes reflect hydrography and circulation in the SB Channel. Nishimoto and Washburn (under review) provide evidence that the closed circulation of persistent eddies can retain fishes through their

[11] A review of some of the relationships and links between particular species and between species and habitats found in the SCB is described in Dailey et al. (1993). A characterization of ecosystem interrelationships is found in Hood (1993), who constructs an energy flow budget for the various components of the ecosystems of the SCB. A discussion of island ecology and biogeography (plant and animal distribution with respect to the islands) is found in Schoenherr et al. (1999: Chapter One).

early life histories. Behavioral responses to abiotic and biotic factors associated with eddies in the SB Channel may also be important in distribution, recruitment and survival (Love et al. 1999).

The marine area north of Point Conception

Point Conception is considered the northern point of the SCB. Near Point Conception, the continental shelf is broad and deflects the south-flowing California Current offshore of the SCB and along the shores of the northern Channel Islands (Brink and Muench 1986; Browne 1994). Point Conception is described as a “transition zone” between two biogeographical provinces, the warm Californian Province and cooler water regime of the Oregonian Province (Horn and Allen 1978; Murray and Littler 1981; Murray and Bray 1993). As described above, Seapy and Littler (1981) describe a third biogeographical province as a transition zone between these two water masses.

Upwelling off the Point Arguello-Point Conception area, where waters are coolest and winds are strongest and persist in directions favorable for upwelling, seems to be the most important factor isolating different seabird species (Briggs et al. 1987). The water masses and the transport of nutrients to the surface attract a variety of birds typical of both cool, northern and warm, subtropical waters, making the SCB an area for diverse avifauna (Parrish et al. 1981 in Baird 1993). When the Southern California Countercurrent (a warmer, saltier water near the coast), is less developed, or when there is a mixing by storms, birds normally associated with the cool western SCB waters or move eastward toward the coast (Briggs et al. 1987).

Scientific evidence suggests a recent northward expansion across Point Conception of some marine species from the warmer-water masses (e.g., Sagarin et al. 1999; Stepien and Rosenblatt 1991). Murray and Littler (1981) among others suggest that the boundary of Point Conception may be less important than previously described by Horn and Allen (1978). Point Conception is described as a transition zone between the two distinct faunal regimes (Horn and Allen 1978). Yet, the importance of Point Conception is less clear. Barry et al. (1995) show a large change attributed to climate variation occurred in the intertidal flora and fauna north of Point Conception (in central California), with many southern species now dominating the community. This change includes a shift in species composition toward warmer-living forms, apparently as a result of increases in sea surface temperature over the 60-year period ending in 1994.

A review of genetic data from several marine species also supports the view that the relationship between the Point Conception and the biogeographic break between Oregonian and California marine biotas is not a clear one (Burton 1998). Burton (1998) shows that the assumed break between biogeographical provinces near Point Conception was an artifact of insufficient geographic sampling.

In summary, some marine species shift geographically in response to climate (Sagarin et al. 1999). These shifts have occurred for thousands of years (Roy et al. 1996). Point Conception is not a clear boundary between biogeographical provinces (Murray and Littler 1981).

The Intertidal Zone

Differences in composition of intertidal macrophyte (seaweed) communities appear to occur along the mainland (Thom 1980; Murray and Littler 1981). Murray and Bray (1993) describe the locations of embayment, intertidal, and subtidal (kelp bed) sites between Point Conception and Mugu Lagoon, and sites located on the northern Channel Islands. Ambrose et al. (1989) summarize the distribution of rocky shore, rock/sand shore, sandy beach, subtidal rocky reef and deepwater rocky bottom for California. Quantitative descriptions of the seasonal distributions and abundances of intertidal macrophytes throughout the SCB are identified and summarized by Littler et al. (1991). Engle (1993) shows how intertidal, subtidal shelf and kelp forest are proportionally represented among the Channel Islands.

Three groups of intertidal macrophyte communities are observed by Murray and Littler (1981): 1) sites nearest Point Conception and the influences of the California Current, 2) sites in the Santa Barbara Channel and the northern reaches of the Santa Monica Bay (Coal Oil Point and Paradise Cove); and 3) sites located south of the Palos Verdes Peninsula and most proximal to the flow of the Southern California Countercurrent. Members of these groups showed similar patterns of species overlap with the central California flora to those indicated for island sites.

Nearshore Processes

Nearshore processes foster the transport and exchange of materials, such as nutrients, between marine habitats, and between marine and terrestrial (coastal) habitats. Murray and Bray (1993) summarize and evaluate the current state of knowledge of the benthic macrophytes (macroalgae, seagrasses, and halophytes) inhabiting SCB. Their focus is on macroalgal and seagrass floristics and biogeography, spatio-temporal dynamics of macrophyte communities for embayment (salt marsh, estuarine, and lagoon), rocky intertidal, and kelp forest habitats, and productivity of macrophyte populations and communities.

Kelp forests are sources of large quantities of drift algae that are transported by currents to adjacent habitats, including soft and rocky benthos, deep channel basins, sandy beaches, rocky shores, and coastal lagoons.[12] Drift algae is an essential source of food for rocky intertidal organisms. These nearshore marine areas are described as essential nursery areas for fishes because of the significant destruction of coastal ecosystem processes in southern California (Murray and Bray 1993; Cross and Allen 1993).

3. Watersheds of the South-central Coast Bioregion

The south-central coast is considered a distinct bioregion[13] of California by government and nongovernment organizations (Jensen 1994; US Fish and Wildlife Service 1993; Conception Coast Project 1999). *The California Resources Agency characterizes the bioregion as one that extends offshore to include the northern Channel Islands and the SB Channel*.[14] The region serves as a geologic, topographic and climatic transition zone supporting a rich diversity of ecosystems. These ecosystems harbor approximately 1,400 native species, of which more than 140 are endemic to the region. Chumash tribes have inhabited this particular bioregion for several thousands of years.

The south-central coastal bioregion includes the watersheds of the Cuyama/Sisquoc/Santa Maria, Santa Ynez, Santa Clara, and Ventura Rivers, as well as the San Antonio Creek watershed and the small coastal watersheds draining the south side of the Santa Ynez mountains (Conception Coast

[12] Fish abundance on reefs is related to the presence or absence of kelp Cross and Allen (1993: 507-513). For more information on habitat groups and island-mainland distribution of kelp-bed fishes off Santa Barbara, California see Ebeling et al. (1980).
[13] For a complete characterization of the meaning of the term bioregion, see McGinnis (1999).
[14] http://www.ceres.ca.gov/ocean/geo_area/bioregions/bioregion_index.html.

Project 1999). The watersheds of the south-coast bioregion include wetlands, estuaries, lagoons, and other systems that are important to marine systems. There are a number of comprehensive summaries of information for the coastal ecosystems of southern California, e.g., tidal wetlands (Zedler 1996), vernal pools (Zedler 1987), coastal salt marshes (Zedler 1984), riparian habitats of the coast (Faber et al. 1989), wetlands (Ferren et al. 1995) and estuaries (Cross and Allen 1993). A statewide overview of coastal ecosystems is found in California State Lands Commission (1994).[15]

Natural bays and estuaries are among the most densely populated and productive of the marine habitats. The species composition of the central California marshes is different from those species identified in southern California (McDonald 1977 in Murray and Bray 1993). Point Conception is the northern most point of location for several plant species. In southern California, over 60 species of fishes are known to frequent bays and estuaries while no less than 159 species of birds have been identified (Fay 1971).

From Rincon to Goleta, 41 coastal creeks enter into the SB Channel from the south side of the Santa Ynez Mountains. These creeks provide important nutrients to the marine environment as well as pollution from creek and river run-off. The importance of terrestrial input of nutrients and sediments to marine habitats (both those that are beneficial and detrimental to ecosystems) have begun to be studied (Mertes 1998; Anderson and Polis 1999).

There is evidence that plumes of sediment from run-off can reach the SB Channel and the Channel Islands (Mertes et al. 1998). More than 80% of the anthropogenic inputs from municipal and industrial discharges, urban runoff, and ocean dumping enters the SCB between Point Dume and Dana Point (Cross and Allen 1993). Studies from the "Plumes and Blooms" project describe water quality from coastal mainland run-off (Dave Siegel, *personal communication*).[16] Mertes et al. (1998) investigate the types and relative magnitude of processes responsible for the transfer of sediment from onshore ridges to the ocean for several coastal river systems in the marine region, e.g., Santa Ynez, Santa Clara and Ventura. This research shows a physical connection between coastal mainland watersheds, run-off, the SB Channel and the marine sanctuary.

Important Coastal Ecosystems

There are a number of important coastal ecosystems between Point Mugu and Cambria. Ferren et al. (1995) provide a classification of coastal wetlands of central and southern California. Many of these coastal wetlands provide important habitat for marine species. For example, the Carpinteria salt marsh provides habitat for many resident and transitory bird species. A total of 139 bird species were identified by Ferren et al. (1996). Like many other coastal systems of southern

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[15] There exist a number of studies that characterize particular coastal areas. For example, a characterization of McGrath State Park and the Santa Clara River is found in J. McIver. 1990. McGrath State Park Natural Preserve: An Analysis of Potential Environmental Impacts from External Sources, and their Management Implications. Department of Landscape Architecture. University of California, Berkeley. May.

[16] See J. Warrick and L.A. Mertes. 1998. Impacts of Large El Nino Driven Storms on the California Coastal Environment. and D.A. Siegel et al. 1998. Plumes and Blooms: Studying the Color of the Santa Barbara Channel. http://www.icess.ucsb.edu/PnB/Projects.html and http://www.icess.ucsb.edu/PnB/Overview.html, respectively.

California, the ecological productivity of the Carpinteria salt marsh is limited by the general impacts of suburbanization on and near the wetland. Ferren et al. (1995) show that those coastal systems in relatively undeveloped areas tend to be the most ecologically productive.[17]

For instance, the coastal ecosystems located between Point Conception and Point Sal described by US Air Force (1997) are sensitive areas that contribute to the overall health of the marine environment. These coastal ecosystems provide valuable habitat for birds, fishes, pinnipeds and other marine species (US Air Force 1997). In general, this area does not include urban and suburban developments, so the coastal ecosystems continue to provide essential nutrients to the marine system of the SCB.[18]

In addition, Mugu Lagoon is one of the highest-quality wetlands remaining in California (Saiki 1997). Mugu Lagoon supports the greatest concentration of water-associated birds between Morro Bay and Anaheim-Bolsa Bay (Calleguas Creek/Mugu Lagoon Watershed Enhancement Plan 1997; Coastal Conservancy 1997). A comprehensive survey of the biological and ecological importance of Mugu Lagoon is found in California State Water Resources Control Board (1979), Onuf (1987), Ledig (1990), Jaques et al. (1996) and Saiki (1997).

Mugu Lagoon is the largest estuarine lagoon in southern California (Onuf 1987). The lagoon is contained entirely within the Naval Academy Station at Point Mugu. Saiki (1997) identifies the occurrence, relative abundance, and fish species assemblages of the lagoon. In addition, Mugu Lagoon is recognized as the closest large mainland roost to the major breeding colony and night roost of California brown pelicans at Anacapa Island, and serves as a staging area for birds and seals moving to and from the island (Jaques et al. 1996).[19] In contrast to suburbanized areas of southern California, Mugu Lagoon (because it is located at the Naval Station) represents a relatively secure roost site due to restricted public access.

In summary, the marine species of the sanctuary are linked to the large-scale system of relationships where biophysical processes of land, water and wind work in concert to form unique species and habitats of the SCB.

IV. Recommended Study Area

The *ideal* study area should include ecological processes and relationships that are needed to protect the marine sanctuary. The study area must also support the priority sanctuary

[17] Several of these important coastal wetlands (e.g., the Goleta slough) are part the Southern California Wetlands Recovery Project, a partnership between federal, state and local governments and nongovernment organizations created to development and implement wetland restoration, enhancement and recovery plans (http://www.coastalconservancy.ca.gov/scwrp/index.html).

[18] The coastal area between Coal Oil Point and Point Sal comprises only 15% of Southern California's coast, yet holds approximately 50% of its remaining rural coastline. The importance of Vandenberg Air Force Base is reflected in the fact that it remains one of the last remaining coastal areas that has not been developed in southern California. The coastal habitats and ecosystems, such as the Santa Ynez River and the San Antonio Creek estuary, remain important nurseries to the sea, and are important to the health and integrity of the marine system.

[19] Mugu Lagoon contains DDT and other contaminants (Saiki 1997).

management goal to protect the marine ecosystems, as specified in the National Marine Sanctuary Act.

Information to support a study area north of Point Sal (as identified in Alternative #4) was not readily available since this marine area has not been systematically studied by marine scientists (Milton Love, *personal communication*). However, there is scientific information that supports a study area which includes more of the SCB, such as information on nearshore lagoon systems of Baja California. The fish assemblages off Baja California are very similar to those of the sanctuary's marine environment (Milton Love, *personal communication*). A characterization of the marine ecology south of Point Mugu, however, is beyond the scope of this report.

This report describes information that generally supports a recommendation for Alternative #3, which includes the marine and coastal area between Point Sal and Point Mugu.

This marine area is recommended for four primary reasons:

1. Murray and Littler (1981) among others (Roy et al. 1996; Sagarin et al. 1999). show that Point Conception may be less important than previously recognized. A large change attributed to climate variation has occurred in the intertidal flora and fauna north of Point Conception (in central California), with many southern species now dominating the community (Barry et al. 1995). This change includes a shift in species composition toward warmer-living forms, apparently as a result of increases in sea surface temperature over the 60-year period from 1934.

2. Information on field observations and studies of the abundance of fishes, birds, marine mammals and coastal ecosystems on Vandenberg Air Force Base and the Mugu Lagoon support the recommendation of the coastal mainland areas between Point Mugu to Point Sal. These coastal ecosystems are essential to marine birds (such as the Brown Pelican). The National Estuaries Program under the US Environmental Protection Agency refers to coastal ecosystems as "nurseries of the sea". Point Mugu does represent the east entrance to the Santa Barbara Channel (an important transition area the includes cold- and warm-water masses) while Point Mugu Basin is a major "sand trap" in the transport of sand into the Channel. Point Mugu is also the closest mainland area to the marine sanctuary (e.g., Anacapa Island).

3. The SB Channel should be included in the study area because it is a representation of two marine biogeographical provinces, the cold- and warm-water masses, and a transition zone between these two water masses. In addition, the SB Channel includes mesoscale mechanisms that are important to the general health of particular species and organisms of the marine sanctuary.

4. The nearshore waters along the coastal mainland include the presence of habitats (such as kelp forests) that are used by a number of marine species of the region (e.g., marine fishes, Cross and Allen 1993: 506-517). They are also important nursery areas for fishes and other marine life.

This report recommends the adoption of a study area between Point Sal and Point Mugu because this area captures a convergence of transition areas, ecological linkages that sustain the marine biological diversity and systems of the CINMS. This study area would capture the ecological links that exist between the marine sanctuary, the transition zones of the SB Channel, the habitats of the nearshore environment, and coastal mainland ecosystems.

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APPENDEX I

Identification and Synthesis of Biological and Physical Published Data on the Marine Environment from Cambria to Pt. Mugu, including the Northern Channel Islands

Summary

This appendix identifies and synthesizes published biological and physical information that was gathered for the northern Channel Islands region which includes the coastal area between Cambria and Pt. Mugu, the Santa Barbara Channel and the southern California islands of Anacapa (*Anyapax*), Santa Cruz (*Limuw*), Santa Rosa (*Wi'ma*) and San Miguel (*Tuqan*).

This appendix represents an initial step to identify, analyze and interpret nearly 30 years of biological and physical information for the marine environment of the CINMS. This information shows that the CINMS is part of the larger systems of the Southern California Bight. This report identifies and synthesizes recently published information on oceanography, zooplankton production, the supply and demand of nutrients, benthic macrophytes, benthic invertebrates, fishes, pinnipeds, cetaceans, southern sea otter, birds and the ecological consequences of El Niño.

I. An Introduction to the Scientific Literature

The northern Channel Islands region (hereafter referred to as the "region") exists within the ecological context of the Southern California Bight (SCB). The SCB includes several interdependent marine ecological systems.

In 1980, information was gathered and synthesized to produce the CINMS 1983 Management Plan. To avoid redundancy and to produce a more useful report, the biological and physical information identified and synthesized for the preparation of the Management Plan (1983) is *not* included in this synthesis.

Since 1980, a number of primary sources of scientific information on the region and the SCB have been published.

- In 1999, the Santa Barbara Museum of Natural History published a 14-volume taxonomic atlas of the benthic fauna of the Santa Maria Basin and the Western Santa Barbara Channel (edited by Scott). This information will be made available on the Museum's webpage in the winter of 1999.

- A useful natural history of the northern Channel Islands are Schoenherr et al. (1999: Chapters 6 and 7), *Natural History of the Islands of California* published by the University of California Press. This book includes a discussion of the ecology of the islands with a particular focus on unique and endemic species of plants on the islands.

- A useful compendium of scientific information on the SCB is Dailey et al. (eds.) (1993), *Ecology of the Southern California Bight: A Synthesis and Interpretation* published by the University of California. In general, Dailey et al. (1993) review and synthesize information published up to the late 1980s. Few sources are used that were published in the early 1990s. In general, Dailey et al. (eds.) describes the various components of the ecology of the SCB. Each chapter is devoted to a particular field of study and research. The last chapter by Hood in Dailey et al. (1993: Chapter 14) is devoted to ecosystem relationships, with a particular focus on the quantitative energy flow through the various ecosystems of the southern California coastal regime.

- Annual reports from the California Cooperative Oceanic Fisheries Investigations (CalCOFI) are key sources of information on the SCB. CalCOFI has been producing data for the SCB since 1950. These investigations make the SCB one of the most studied marine systems in the world. Reports and raw data is available at *http://www-mlrg.ucsd.edu/calcofi/*

- The Proceedings from the five California Islands Symposiums are sources of information for the region. Proceedings from the last symposium (1999) include essays that are relevant to this study, including Dugan et al. (1999 in press) and Lafferty and Kushner (1999 in press), and will be published this winter.

- Information in essays on the subject of marine reserves and the region are unpublished and currently under review at the journal *Ecological Applications*. The June 2000 issue will focus on the subject of marine reserves and will include papers from investigators who are participating in several reserve work groups at the National Center for Ecological Analysis and Synthesis (NCEAS). One paper includes a comprehensive table of commercially and recreationally important marine fishes and invertebrates of the Channel Islands region. Unpublished sources were not included in this analysis.

- A collection of sources and references (approximately 80,000 citations) on the ecology of the region is available from the Channel Islands National Park, CINMS and the SB Natural History Museum. This information is described on the Museum's webpage which is located at *http://www.sbnature.org/tour2.htm*.

- Environmental documents and environmental impact reports/statements (EIR/S) on the coastal mainland, such as Vandenberg Air Force Base's *Final Integrated Natural Resources Management Plan* (US Air Force (1997), are important sources of information for the region.

- Environmental documents and EIR/S on the offshore continental shelf and submerged lands are important sources of information for the region. These reports often include an analysis of the biological characteristics of particular offshore areas.

- Because of new technologies (e.g., high frequency radar) and interdisciplinary studies, starting in the late 1980s, some information related to ecological links and ecosystem relationships have begun to be published.

II. The Ecological Setting

The Channel Islands are distributed along the edge of the continental borderland of the SCB and serve as the breeding grounds for a rich array of marine species. The region is part of the SCB, which is commonly delineated as a system that extends west and south of Pt. Conception to the International Border with Mexico. Water transport within the SCB is largely dictated by the southern flow of the California Current and the prevailing winds from the northwest. Together these forces drive cold water from the North directly into the Northern Channel Islands.

This mass movement of water can fuel an upwelling of cold nutrient-rich water, usually in the late spring to early summer period. Upwelling is essential for the health of the ecosystems and organisms of the SCB.

The California Current is forced offshore near Pt. Conception creating a large eddy current referred to as the Santa Barbara Gyre. This gyre system generally flows in a counter-clockwise direction between the Santa Barbara mainland coast and the Channel Islands in the Santa Barbara Channel.

Another large water transport system in the SCB is the Southern California Counter Current that draws warmer water from the south and forces the water northwest through the Channel Islands.

The confluence of these major currents has created, and continues to shape, a diverse and rich system of habitats and species comprised of open ocean and nearshore habitats.

The mean circulation in the SCB is dominated by the poleward-flowing Southern California Countercurrent, which may be thought of as a large scale eddy in the California Current. The California Current, which is fed by the West Wind Drift, is the eastern limb of the North Pacific gyre. It flows equatorward along the west coast of the US throughout the year. This current turns shoreward near the southern US border, and a branch of the current turns poleward into the SCB, where it is known as the Southern California Countercurrent. This countercurrent is strongest in summer and winter.

The SCB provides essential nutrients and marine habitats for a range of species and organisms.

Submarine canyons, ridges, basins and seamounts provide unique habitats within the SCB. The basins provide habitats for a significant number of mid-water and benthic deep sea fishes very near the coast, including the Islands. Nearshore waters provide a variety of habitats. Soft substrates, such as bays and estuaries, exposed sandy beaches, shelves, and slopes area abundant along the Islands. Hard substrates, such as the rocky intertidal, shallow subtidal reefs, deep rock reefs, and kelp beds are abundant around the Islands as well. Kelp beds form a unique shallow water community and provides a haven for a complex array of algal species, invertebrates, and fish. The ecology of the shallow subtidal and intertidal assemblages is essential habitat for marine organisms, such as benthic marine invertebrates. Over 5000 species of benthic marine invertebrates exist in the SCB.

Overall, the health of marine systems depends on a healthy relationship between circulating water masses and currents, various geochemical processes, oceanographic processes, microorganisms, phytoplankton, zooplankton, a rich flora of benthic macroalgae and seagrasses, benthic invertebrates, and the distribution and abundance of other nutrients and organisms. Ecological production in the SCB depends on nutrients from storm runoff, aerial fallout, and seasonal upwelling.

1. Oceanographic Characteristics

Comprehensive surveys of the scientific literature on the physical oceanography of the Santa Barbara Channel are provided by Harms and Winant (1998) and Hickey (1992, 1993) and Brink and Muench (1986). A general summary of the oceanography of the Santa Barbara Channel and outlying regions is provided by Love et al. (1999).

Harms and Winant (1998) describe six circulation patterns in the Santa Barbara Channel while Hickey (1993) incorporates the results of CalCOFI data sets to provide an up-to-date characterization of the currents and water properties in the region. Generally, these studies show that circulation within the SBC is highly variable in time and space, and is determined by the relative strengths of wind stress and a deep-water pressure gradient through the channel.

Mesoscale hydrodynamic features within this region such as jets, meanders, eddies and fronts are apparent in sea surface temperature images and are manifested by local-scale interactions of wind, water, mass currents and tides (Owens 1980). Little has been published on the mesoscale circulation outside of the channel around the islands (Nishimoto 1999).

Lagerloef and Bernstein (1988) and Hendershott and Winant (1996) describe cyclonic gyre circulation pattern in the SB Channel that persist year-round. Little is known of the periodicity or evolution of the mesoscale gyre or the processes that maintain it (Love et al. 1999).

Within the last several years, interdisciplinary research that combines oceanographic data with field studies on fishes may be important for the management plan. A recent summary field studies conducted in 1995, 1996 and 1997 by Nishimoto (1999) and by Nishimoto and Washburn (under review) examine the relationship between what they refer to as the “Santa Barbara Channel eddy” and the abundance of pelagic juvenile fish populations within the cyclonic (counter-clockwise) eddy. This information may be important in the design of “no-take” marine reserves to protect fishes (Nishimoto 1999).

2. Zooplankton Production

Recent information focuses on the abundance and distribution of microorganisms and nutrients in the region. Phytoplankton represent an essential part of the ecosystems of the SCB. A comprehensive summary of data from CalCOFI on phytoplankton is described by Hardy (1993) while a review and summary of information on zooplankton is provided by Dawson and Pieper (1993).

Newly described phylogenetic lineages within the domain *Archaea* have recently been identified and described as significant components of marine picoplankton assemblages. To better understand the ecology of these microorganisms, Massana et al. (1997) investigated the relative abundance, distribution and phylogenetic composition of *Archaea* in the Santa Barbara Channel. Massana et al. (1997) show that marine planktonic crenarchaeal and euryarchaeal groups thrive in different zones of the water column.

A review of the scientific literature on zooplankton of the SCB can be found in Dawson and Pieper (1993) and Eppley (1986). Macrozooplankton biomass shows a large decrease which started in the mid 1970s (Roemmich and McGowan 1995). Hayward et al. (1996) and McGowan et al (1998) show that large-scale biological responses in the marine environment due to climatic variations in the atmosphere has resulted in changes in geographical ranges and spatial patterns of species and in community structure.

3. The Supply and Demand of Nutrients

In an investigation of food supply and demand in the eastern North Pacific off the central California coast between 1989 and 1996, Smith and Kaufmann (1994) show a long-term increase in sea surface and upper water column temperatures and physical stratification in the system. Because of this stratification, the depth of mixing nutrient-rich water has shoaled off, resulting in a lower rate of supply of nutrients to the euphotic zone; a decrease in productivity and a general decline of zooplankton and other species (e.g., larval fish production, sea birds, kelp production and a shift in benthic, intertidal community structure.) The investigators show that a long-term deficit in the supply of food necessary to meet the metabolic demands of the sediment community is unsustainable. Despite the decline in food supply, the food demand of the deep-benthic sea community remained constant. This issue is also addressed and critically reviewed by Druffel and Robison (1994).

The data suggests that if long-term climate change continues, one result will be a continued reduction in the supply of food to the deep-sea benthos. This reduction could produce a concomitant shift in the characteristics and in the composition of the abyssal community.

4. Benthic Macrophytes

A comprehensive review of field studies on benthic macrophytes and seagrasses of the SCB is found in Murray and Bray (1993). Murray and Bray (1993) summarize and evaluate the current state of knowledge of the benthic macrophytes (macroalgae, seagrasses, and halophytes) inhabiting SCB. Their focus is on macroalgal and seagrass floristics and biogeography, spatio-temporal dynamics of macrophyte communities for embayment (salt marsh, estuarine, and lagoon), rocky intertidal, and kelp forest habitats, and productivity of macrophyte populations and communities.

Quantitative descriptions of the seasonal distributions and abundances of intertidal macrophytes throughout the SCB are identified and summarized by Littler (1991).

Most research on subtidal macrophytes has focused on kelp communities and the biology of Macrocystis (Tegner and Dayton 1987 provide a summary). Knowledge of subtidal macrophyte communities other than those dominated by kelp is limited (Murray and Bray 1993).

There are also key sources of information on the region.

- There is a 14 volume taxonomic atlas of the benthic fauna of the Santa Maria Basin and the Western Santa Barbara Channel (P. Scott, editor) available at the Santa Barbara Natural History Museum.
- Murray and Bray (1993) review field studies for the region and describe the locations of embayment, intertidal, and subtidal (kelp bed) sites between Pt. Conception and Mugu Lagoon and sites located on the northern Channel Islands.
- Ambrose et al. (1989) summarize the distribution of rocky shore, rock/sand shore, sandy beach, subtidal rocky reef and deepwater rocky bottom for California.
- Engle (1994) shows how intertidal, subtidal shelf and kelp forest are proportionally represented among the Channel Islands.
- Ferren et al. (1995) provide a classification of coastal wetlands of central and southern California.

Few data exist for lagoons, modified estuaries (harbors and marinas), salt marshes, nonkelp subtidal, and deep-water macrophyte communities within the region.

5. Benthic Invertebrates

A comprehensive survey of marine benthic invertebrates, with a particular focus on ecological interactions and life histories of macro- and megabenthos that inhabit shallow areas (< 30 m), is found in Thompson et al. (1993). No estimates of the total number of species in the region have been made. Other reviews of the benthic invertebrates have been made by the Southern California Coastal Water Research Project (1973), the Southern California Ocean Studies Consortium (1974), and Bakus (1989). Taxonomic listings have been compiled by Straughan and Klink (1980) and the Santa Barbara Natural History Museum (see above).

6. Fishes

Cross and Allen (1993) review the ecology of fishes in the major habitats of the SCB. The investigators emphasize spatial and temporal patterns of distribution and abundance and the relationships between physical forcing processes and biological processes. To some extent, recruitment and causes of changes in abundances are discussed.

Data from the California Department of Fish and Game (CDFG) show decreases in harvest for most categories of groundfish, California sea urchin landings, landings of swordfish and selected shark species, Pacific Mackerel, Pacific Herring, California halibut, market squid (for the period 1997-1998) among others (e.g., CalCOFI 1995, 1998). A comprehensive analysis of the general decline in long-term productivity of 19 nearshore fishes and invertebrates that supported important fishes in California, 1947 - 1986, from landings data is found in Dugan and Davis (1993).[20]

[20] J.E. Dugan has also prepared a comprehensive table on commercially and recreationally important fishes and invertebrates of the Channel Islands region

Some fisheries have increased, according to analysis by CalCOFI (1998). California live-fish landings between 1988 - 1997 and the recent rebuilding of the Pacific sardine fishery are examples.

A sample of the relevant scientific literature on fishes of the region are:

- Engle (1993) describes the distributional patterns of rocky subtidal fishes around the California Islands.
- Ebling et al. (1980) describes habitat groups and island-mainland distribution of kelp-bed fishes off Santa Barbara, California.
- Holbrook and Schmitt (1996) show that populations of many inshore fish species have declined markedly since the mid-1970s.
- A comprehensive examination by Love et al. (1998) of long-term trends in the SCB commercial fishing vessel rockfish fishery shows a substantial decline from 1980 to 1996, with extremely low catches from 1993 to 1996. These findings are also supported by the earlier work of Stephens et al. (1986, 1994).
- Vojkovich (1998) describes the market squid fishery in the region.
- A characterization of fish assemblages on mussel mounds surrounding oil platforms in the Santa Barbara Channel and Santa Maria Basin is found in Love et al (1999b). Love et al. (1999a) also describe the role of natural reefs and oil and gas platforms on rocky reef fishes in southern California, with a particular focus on habitats in the region.

- The distribution of juvenile fishes (e.g., rockfishes) and its relation to water masses in the Santa Barbara Channel for the period between 1995 and 1997 is found in Nishimoto and Washburn (under review).

There is data that shows that recruitment of many temperate reef fishes is influenced by abundance and species composition of macroalgae within an area (Carr 1994). Macroalgal dynamics can cause year-to-year variation in the size and age structure of local fish populations. Local populations and communities of fishes respond to sources of variation other than anthropogenic perturbations, including variable recruitment (Caley et al. 1996) and trends in resource availability (Holbrook and Schmitt 1996).

Steelhead rainbow trout (*Oncorhynchus mykiss*) were once abundant in this region's coastal streams. In the early 1960s, total statewide abundance was estimated to be 600,000 adults. Southern steelhead (those inhabiting coastal streams south of San Francisco Bay) were formerly found in coastal drainages as far south as the Rio Santa Domingo in northern Baja California. Those steelhead south of Pt. Conception are considered "evolutionary significant units" and are thought of as a separate sub-species. At present, Malibu Creek (south of Pt. Mugu) is thought to be the southern-most stream containing a known spawning population. The estimated abundance in streams south of Pt. Conception is probably on the order of a 100 - 300 adults (Nehlson 1991; Pacific Fishery Management Council 1996). Out of the 41 creeks from Rincon Point to Goleta, 6 creeks are believed to have steelhead runs (Greg Fusaro, *personal communication*).

7. Pinnipeds

A general characterization of pinnipeds (diet and feeding, trophic impacts, natural mortality and environmental concerns) in the SCB is found in Bonnell and Dailey (1993). Pinnipeds inhabit

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for a paper currently under review for publication.

both the Channel Islands (primarily San Miguel Island) and the coastal mainland. A comprehensive report on all stocks of marine mammals for the Pacific Region is found in Barlow et al. (1997, 1998a, b).

Table 7.1 describes the estimated populations, stock area, year of census of pinnipeds in the vicinity of the region and the total annual mortality rate due to California gill nets.

[Table 7.1 about here]

Pinnipeds inhabit sandy beaches and rocky intertidal areas for pupping, breeding, molting and resting. Populations of pinnipeds appear to be influenced by climatic events such as El Niño (Barlow et al. 1998b).

California sea lions (*Zalophus californianus californianus*), Pacific harbor seals (*Phoca vitulina richardsi*), northern elephant seals (*Mirounga angustirostris*), and northern fur seals (*Callorhinus ursinus*) breed on the Channel Islands, with the largest rookeries on San Miguel Island (Stewart et al. 1997). California sea lions, northern elephant seals and Pacific harbor seals also inhabit Santa Rosa Island (NMFS 1994). Guadalupe fur seals (*Arctocephanlus townsendi phillipii*) breed on Isla de Guadelupe off Baja California but occasionally they have been observed on the Channel Islands (CDFG 1990; NMFS 1993). A total of 43 Guadalupe fur seals were sighted during the summer at San Nicolas and San Miguel Islands between 1969 and 1986 (Stewart et al. 1997).

Along the coastline of VAFB several species of pinnipeds have been observed (harbor seals, California sea lions, and elephant seals) (US Air Force 1997). Harbor seals on VAFB haul out at a total of 19 sites between Pt. Sal and Jalama Beach (Roest 1995). The average baseline count of harbor seals is 327 (Roest 1995). Haulout sites on the North Base are concentrated near Purisma Point while haulout sites on South Base are concentrated near Rocky Point. Both areas are primarily used by harbor seals (NMFS 1995). In addition, the area surrounding Pt. Sal, north of VAFB, is a haulout area for California sea lions. Sea lions do not breed on the coastline of VAFB. Pt. Sal, which lies north of VAFB, is the area most intensely utilized as a haulout by sea lions (in particular, the sea lions use Lion Rock, see Roest 1995).

Along the VAFB coastline, the population of harbor seals between 1993 and 1995 ranged from a low of 124 individuals to a high of 680 individuals (US Air Force 1996). No less than 100 sea lions can be observed at Lion Rock (Roest 1995). This location is considered a resting area for sea lions during their seasonal migrations to and from the breeding grounds (Chambers 1979). Roest (1995) indicates that elephant seals periodically use the beaches within the region since 1981.

The Northern fur seal on San Miguel Island is the southern extent of the species' range. The population of northern fur seals on San Miguel Island has increased steadily since the early 1970s, except during the El Niño of 1982 to 1983 (DeLong 1982) and the El Niño of 1997 (DeLong et al. 1998). In 1983, the counts decreased dramatically by 63% (DeLong and Antonelis 1991). The 1997 live pup count of 2,706 was the highest reported at the San Miguel colony since it was discovered in 1968. In part because of the El Niño event, it is expected that there will be no survival of pups from the 1997 cohort (DeLong et al. 1998 at *http://nmml.afsc.noaa.gov.el nino*). Delong et al. (1998) estimate that the population will likely decline in the next few years due to the pup and adult mortality predicted in 1998 from El Niño.

Harbor seal haulout sites are widely distributed on mainland and offshore islands, including intertidal sandbars, rocky shores, and beaches. Harbor seals do not make extensive pelagic migrations though some long distance movement of tagged animals along the US west coast have been recorded (up to 550 km) (Barlow et al. 1995; CDFG 1990). Harbor seals have displayed a strong fidelity for haul out sites (Pitcher and McAllister 1981). Recent genetic analysis of harbor seals provides evidence that there are three separate harbor seal stocks along the continental US. Samples from Washington, Oregon and California demonstrate a high level of genetic diversity and indicate that the harbor seals of inland Washington possess unique haplotypes not found in seals from the coasts of Washington, Oregon and California (Lamont et al. 1996). California harbor seals are considered a separate stock. Barlow et al. (1995) estimated a population of 34,554 in 1994. At that time the population appeared to be growing. The impacts of El Niño on pups and adult California harbor seals is unknown.

The two major California sea lion rookeries in the Channel Islands are on San Miguel and San Nicolas Islands. Stewart et al. (1997) estimated that about 95% of the 16,000 to 17,000 pubs born in the Channel Islands in 1986 were from these rookeries. Seasonal movements of adult males are described by Reeves et al. (1992). Adult females may remain near these two rookeries year-round (NMFS 1993). An increase in the California sea population occurred from 1970 to 1989; the total population increased from an estimated 10,000 to 87,000 in the Southern California Bight (NMFS 1993). Between 1985 to 1987, population data indicated that most of the individuals on the northern Channel Islands were on San Miguel Island, with a population ranging from 2,235 to over 17,000. Barlow et al. (1995) estimated that the population has been growing at 8.2% per year.

Northern elephant seas range from Baja California to Vancouver Island with major rookeries on San Miguel and San Nicolas Islands (Reidman 1990; Reeves et al. 1992; Stewart and DeLong 1993). They also have been observed at selected sites on the mainland from Point Reyes to Piedras Blancas (Roest 1995). Results of tagging and telemetry research indicate that weaned elephant seal pups from the Channel Islands move north in late winter and spring, arriving at Ano Nuevo and the Farallon Islands in autumn and winter (Reeves et al. 1992). The California stock was estimated at 73,500 in 1991 (NMFS 1993) and this number has increased in the Channel Islands since the early 1990s (Barlow et al. 1995; Stewart et al. 1994). Barlow et al. (1995) also indicate that the Channel Islands rookeries account for 85% of the births in California.

Until 1977, a small rookery of Steller sea lions (*Eumetopias jubatas*) existed on San Miguel Island but there has been no breeding in the area since 1981 and there has been no sightings since 1984 (Stewart et al. 1997). The most current surveys from 1990 indicate a total of 63,000 Steller sea lions in the Pacific Ocean, with only 100 in the SCB (NMFS 1993).

8. Cetaceans

Table 8.2 describes estimated populations, stock area, the status of the population in the SCB, year of census of cetaceans in the vicinity of the region, and the annual mortality rate due to California gill nets. As Table 8.2 indicates, most cetaceans do not restrict their ranges to the boundaries of the study area.

[Table 8.1 about here]

A general characterization of cetaceans (diet and feeding, trophic impacts natural mortality and environmental concerns) in the SCB is found in Bonnell and Dailey (1993). Our understanding of marine mammal fauna in the SCB is fairly well described compared to other parts of the ecosystems of the eastern North Pacific. A great deal of new information has been gathered since the early 1980s that is described in Bonnell and Dailey (1993). The focus of this synthesis is on cetaceans that are year-round residents (indicated by “c” in Table 8.2).

The Common dolphin in California is part of a continuous population that extends to waters offshore Mexico and into the eastern tropical Pacific (NMFS 1993; Perryman and Lynn 1993). Historically, they have been observed primarily south of Pt. Conception (Dohl et al. 1986).

The Pacific white-sided dolphin is found throughout the temperate northern North Pacific Ocean from the coasts of Japan and Baja California, Mexico northward. The species are observed year-round. Sighting patterns from aerial and shipboard surveys conducted in California, Oregon and Washington at different times of the year suggest seasonal north-south movements, with animals found primarily off California during the colder winter months and shifting northward into Oregon and Washington as water temperatures increase in late spring and summer (Forney 1994).

Dall’s porpoise are endemic to temperate waters of the North Pacific, and are observed most frequently in continental slope and oceanic waters, but they also occur over shelf waters (NMFS 1993). As oceanographic conditions change evidence suggests that these animals also move seasonally (Barlow et al. 1995).

Harbor porpoise are found in the Pacific Ocean in coastal and inland waters from Pt. Conception to Alaska and across to Kamchatka and Japan (Gaskin 1984). Regional differences in pollutant residues in harbor porpoise indicate that they do not mix freely between California, Oregon and Washington (Calambodkidis and Barlow 1991). Barlow and Hanan (1997) recommend that the harbor population that inhabits central California from Point Conception to the Russian River be treated as a separate stock. The harbor porpoise is the only small cetacean of concern that may be found in the vicinity of VAFB (US Air Force 1997).

Bottlenose dolphin are found in groups of 10 to 20 within about 1 km of shore primarily from Pt. Conception south into Mexican waters (Hansen 1990). The offshore bottlenose dolphin inhabits a few miles of the coast to at least 300 nautical miles offshore, and occurs in groups of 25 to 300 animals. It is often observed in association with other species such as sperm and gray whales (NMFS 1993).

Risso’s dolphins are commonly observed on the shelf in the SCB and in slope and offshore waters of California, Oregon and Washington. Animals found off California during the colder water months are thought to travel northward into Oregon and Washington as water temperatures increase in late spring and summer (Green et al. 1992).

Most mysticete (baleen whale) species occur offshore California and their numbers are apparently increasing since being commercially hunted (Barlow 1993). The majority of the California gray whale stock migrates through the SCB and waters north of Pt. Conception. The major migratory routes are thought to lie between several hundred yards offshore and the Channel Islands (Forney and Barlow 1993). Humpback whales have been observed to travel along the Santa Rosa-Cortez Ridge and, at times, enter the Santa Barbara Channel (Schulman 1984; NMFS 1993). Blue whales winter from central California to about 20 degrees north latitude and summer from central California to the Gulf of Mexico (NMFS 1993). One group of this population migrates from Mexico to feed in California waters from June to November. This group may be a distinct stock from the second group which feeds north of California. Minke whales are present year-round in the SCB and have been reported within a few miles of the leeward sides of San Miguel, Santa Rosa, Santa Cruz, and Anacapa Islands (Leatherwood et al. 1987).

The relationship between cetaceans and other marine animals remains unclear. It remains unclear how marine mammal populations respond to changes in oceanographic conditions and climatic events, such as El Nino. Moreover, the impacts of marine mammals on their food resources in the SCB is also unclear.

9. Southern Sea Otter

The southern sea otter (*Enhydra lutris nereis*) is a distinct population of twelve species of otters worldwide and are members of the mustedlid family of marine mammals (Anderson et al. 1996). A population of roughly 2,400 southern sea otters live along the stretch of less than 400 km off the California coast around Monterey Bay (US Fish and Wildlife Service 1996; Reidman and Estes 1990). The historical range of the sea otter extended across the Pacific rim in a wide arc from Morro Hermosa in Baja California to the island of Hokkaido in northern Japan (Ogden 1941). In California, estimates of historical population numbers range from 16,000 - 20,000 (Ralls et al. 1983). Habitat suitable for the otter exists south of Pt. Conception (DeMaster et al. 1996). A translocated population of roughly 12 - 16 independent otters is located at San Nicolas Island but this colony continues to decline (Benz 1996). About 100 individuals have been observed south of Pt. Conception at Coho Bay. Sea otters are found along rocky, sandy and mixed shores, but are most common along rocky shores and prefer kelp habitat. This population is below equilibrium density (Bodkin et al. 1996) and is declining (Estes et al. 1996).

10. Birds

As with migrating populations of Cetaceans and Pinnipeds, most birds do not restrict their ranges to the region. More than 195 species of birds use coastal and/or offshore aquatic habitats in the SCB. According to Baird (1993), population numbers for the entire SCB are not accurately documented.

Hunt et al. (1980) and to some extent Briggs et al. (1987) describe the abundance of sea birds breeding on the California Channel Islands and at-sea, respectively, while the US Air Force (1996, 1997) describe the birds that use the coastal habitats on Vandenberg AFB. Baird (1993) summarizes much of the published and unpublished literature on distribution, abundance, migration, breeding biology, and feeding ecology of marshbirds (herons, rails, cranes, and ibises), waterbirds (ducks, geese, coots, and grebes), shorebirds and seabirds (those birds that live or reside near or on coastal or offshore habitats). Accounts of other seabird species that inhabit the SCB can be found in Garrett and Dunn (1981). Additional information on birds (and mammals) that inhabit the northern Channel Islands are available at CINMS. This information was identified and gathered by Dugan (*personal communication*).

A natural history of bird populations in relation to the introduction of exotic species (predators such as cats and rats and habitat destroyers such as goats and rabbits) for the northern Channel Islands is provided by Schoenherr et al. (1999: Chapter 6) and Baird (1993). Abundance and distribution of seabirds at breeding colonies in the Channel Islands is described by Briggs et al. (1987) and Baird (1993, pp. 558-573).

Evidence suggests that the abundance of oceanic birds in the region and the SCB have declined steadily since 1988 (Veit et al. 1996, 1997). There are many reasons from this, such as development of coastal habitat (wetlands and saltwater marshes) (California Nature Conservancy 1987; Baird 1993; Ferren 1995), pollution (CalCOFI 1988), commercial fishing (Hunt et al. 1981) and climate change. Important coastal locations in the study area that are important for marshbirds, waterbirds, shorebirds and seabirds include the Santa Ynez River Estuary and San Antonio Creek Estuary (on VAFB), Devereux Slough, Goleta Lagoon, Carpinteria Marsh, Santa

Clara River Estuary, and Mugu Lagoon (Baird 1993). Detail on the Santa Ynez River Estuary and San Antonio Creek Estuary is described by Tetra Tech, Inc. (1996). Coastal development in or near many of these habitats and the general destruction of southern California's wetlands has significant impact on the health of various bird species (California Nature Conservancy 1987 among others). There is also expressed concern that the squid fishery may be impacting particular bird populations that inhabit the Channel Island. This is a concern that scientists are beginning to explore.

In addition to the loss of habitat, ocean warming and zooplankton abundance have been linked to long-term change in pelagic bird abundance in the California Current system (Veit et al. 1996, 1997). In an analysis of CalCOFI data from 65 oceanographic stations from the northern most line based at Avila Beach, San Luis Obispo to La Jolla, San Diego from 1987 to 1994, Veit et al. (1996, 1997) show that the number of seabirds declined significantly. The overall trend in bird abundance in 1987 to 1994 was negative, and this trend was mirrored in the decline of the most numerous species that was recorded, the sooty shearwater. Veit et al. (1996) believe that this reduction reflects considerable biological change within the California Current System. Veit et al. (1996, 1997) indicate that ocean warming and climatic events (such as El Nino) change pelagic bird abundance within the California current system.

IV. The Disturbance Regime

Both natural disturbances, such as a climatic events, and human impacts to marine systems can lead to large-scale environmental change, or what is referred to as *regime shifts* by marine scientists. These regime shifts change the basic nature of marine ecosystems for several decades at a time (or on the order of several human generations). Because of these regime shifts and the lack of information that we have on the natural history of the SCB, it is difficult to define a *baseline state* for the marine ecosystems of the SCB.

The El Niño Southern Oscillation (ENSO) events have had dramatic effects on marine ecosystems (*http://www.pmel.noaa.gov/toga-tao/ensodefs.html).* El Nino impacts include population shifts in commercially harvested species, such as squid, rockfish and lobster; transport of enormous volumes of sediments and suspended materials from the mainland to coastal and offshore waters; and disturbance to critical marine habitats, notably storm and water temperature damage to kelp forests. ENSO events can be considered short-term variations. Longer climatic cycles occur.

El Niño (EN) is characterized by a large-scale weakening of the trade winds and warming of the surface layers in the eastern and central equatorial Pacific Ocean. El Nino events occur irregularly at intervals of 2-7 years, although the average is about once every 3-4 years. They typically last 12-18 months, and are accompanied by swings in the Southern Oscillation (SO), an interannual see-saw in tropical sea level pressure between the eastern and western hemispheres. During El Nino, unusually high atmospheric sea level pressures develop in the western tropical Pacific and Indian Ocean regions, and unusually low sea level pressures develop in the southeastern tropical Pacific. SO tendencies for unusually low pressures west of the date line and high pressures east of the date line have also been linked to periods of cold equatorial Pacific sea surface temperatures (SSTs) sometimes referred to as La Nina.

The Southern Oscillation Index (SOI), defined as the normalized difference in surface pressure between Tahiti, French Polynesia and Darwin, Australia is a measure of the strength of the trade winds, which have a component of flow from regions of high to low pressure. High SOI (large pressure difference) is associated with stronger than normal trade winds and La Nina conditions, and low SOI (smaller pressure difference) is associated with weaker than normal trade winds and El Nino conditions. The terms ENSO and ENSO cycle are used to describe the full range of variability observed in the Southern Oscillation Index, including both El Nino and La Nina events.

In general, evidence points to a large-scale persistent biological response to the climate regime shift in the California Current:

- Climate-ocean variations have disturbed and changed zooplankton production (among other characteristics of coastal ecosystems) (McGowan et al 1998). Over the period 1950 to 1980, plankton varied positively with periods of increased transport of cool, relatively fresh water from the north (Chelgon et al. 1982). Reduced macrozooplankton described by McGowan et al. (1998) has had a major impact at higher trophic levels.
- The biological consequences of the 1983 to 1984 West Coast El Nino were dramatic. Zooplankton and kelp forests declined greatly, as did many individual populations of fish and invertebrates (Dayton and Tegner 1990). According to Tegner et al. (1996, 1997), Tegner and Dayton (1991), and Dayton et al. (1992) kelp forests that suffered great damage during these events are now systematically smaller and depauperate, a trend that began in the late 1970s. Since the late 1970s, macrozooplankton volume in the California Current has declined over 70%, in concert with increasing sea surface temperatures (Roemmich and McGowan 1995; McGowan et a. 1998). In related studies, Tegner et al. (1996) show that the abundance and stipe number (an index of individual size) of southern California populations of the kelp *Macrocystis pyrifera* have undergone a substantial decline, following the trend of increasing sea surface temperature. Comparison with historical stipe data from 1957, 1973, and 1974 indicates up to two-thirds reductions in standing biomass since 1957 in southern California kelp forests. There is some evidence that El Nino also influences the abundances of fishes. However, it is difficult to attribute the role of climate variability in the regulation of fish populations (as a reflection of ecosystem disturbance) (Botsford et al. 1997).
- The biological consequences of the 1997 to 1998 El Nino are not fully known, but there are numerous scattered reports of large population declines, bird and mammal mortalities, and range shifts similar to those of 1983 to 1984 (McGowan et al 1998). Pinniped pup counts for California sea lions, harbor seals and Northern fur seals dropped (Barlow 1998a, b). Systematic, spatially extensive, oceanic seabird counts in the SCB did not begin until 1987, but abundances have declined 90% since then (Veit et al. 1996; McGowan et al. 1997).
- A large change attributed to climate variation occurred in the intertidal flora and fauna north of the region (in central California), with many southern species now dominating the community (Barry et al. 1995). These changes include a shift in species composition toward warmer-living forms, apparently as a result of increases in sea surface temperature over the 60-year period ending in 1994.

There is also some indication that the frequency of these climatic events may be increasing (McGowan et al. 1998).

V. The Need for Additional Information and Analysis

This report identified and characterized a number of published reports and articles on the region. In many circumstances, information for the larger ecological context of the SCB was included in this analysis. There remains a paucity of published accounts of large-scale ecological links and relationships in the region. Additional information on large-scale ecosystemic relationships and ecological links are needed (Costanza et al. 1998) to better understand the natural history and character of the region's systems and, ultimately, to "protect" the components of these systems.

Table 7.1
Estimated Populations, Stock Area, and Year of Census of Pinnipeds of the Southern California Bight and in the Vicinity of the Region

Common Name	**Stock Area**	**Genus/Species**	**Total Est. Pop./ Year of Census**	**Est. Pop. on San Miguel Island****	**Est. Deaths Due to CA Gill Nets**
California sea lion	US	*Zalophus californianus*	111,339 (1996)	80000	974
Steller sea lion	Pacific	*Eumetopias jubatus*	63000 (1990)*	0	unknow n
Harbor seal	CA	*Phoco vitulina*	27962 (1996)	1200	243
Northern elephant seal	CA breeding	*Mirounga angustirostris*	51,625 (1996)	50000	145
Guadalupe fur seal	Mexico to CA	*Arctocephalus townsendi*	3028 (1996)*	0	0
Northern fur seal	San Miguel Island	*Callorhinus ursinus*	6720 (1998)	12000 (1997)	0

Source: Barlow, J., P.S. Hill, K.A. Forney, and D.P. DeMaster. 1998. U.S. Pacific Marine Mammal Stock Assessments: 1998. US Department of Commerce. NOAA-TM-NMFS-SWFSC-258; Julian, F. and M. Beeson. 1998. Estimates for marine mammal, turtle, and seabird mortality for two California gillnet fisheries: 1990-1995. Fishery Bulletin 96: 271-84.
* Indicates no recent observation of the population in the Northern Channel Islands.
** R.L. DeLong and S.R. Melin. 1999. Thirty Years of Pinniped Research on San Miguel Island. Alolkoy (Fall 1999): 3-4.

Table 8.1
Estimated Populations, Stock Area, and Year of Census of Cetaceans in the Vicinity of the Region*

Common Name and Status of Population in SCB	Stock Area	Genus/Species	Estimated Pop./ Year of Census	Total Annual Mortality in California Gill Net Fisheries
North Pacific right whale [r]	CA/OR/WA	*Eubalaena glacialis japonica*	Unknown	Unknown
Gray Whale [m+]	California	*Eschrichtius robustus*	2788 (1993)	Unknown
Blue Whale [m]	California/Mexico	*Balaenoptera masculus*	1463 (1996)	.2
Fin Whale [m]	CA/OR/WA	*B. physalus*	1044 (1996)	0
Sei Whale [mu]	Eastern North Pac.	*B. borealis*	Unknown	0
Bryde's Whale [r]	Eastern Tropic Pac.	*B. edeni*	11163 (1996)	0
Minke Whale [mc]	CA/OR/WA	*B. acutorostrata*	440 (1998)	3.6
Humpback Whale [rm]	CA/OR/WA	*Megaptera novaeangiliae*	563 (1996)	1.8
Sperm Whale [ru]	CA/OR/WA	*Physeter catodon*	995 (1996)	4.6
Pygmy Sperm Whale [ru]	CA/OR/WA	*Kogia breviceps*	1920 (1996)	2.8
Dwarf Sperm Whale [ru]	CA/OR/WA	*K. simus*	Unknown	0
Mesoplodont Beaked Whales [ru]	CA/OR/WA	*Mesoplodon spp.***	2840 (1998)	13
Cuvier's beaked Whale or Goose-beaked Whale [ru]	CA/OR/WA	*Ziphius cavirostris*	4980 (1996)	26
Baird's Beaked Whale [ro]	CA/OR/WA	*Berardius bairdii*	312 (1996)	1.2
Pilot Whale, short-finned [c]	CA/OR/WA	*Globicephala macrorhynchus*	717 (1996)	13
Risso's dolphin [c]	CA/OR/WA	*Grampus griseus*	13087 (1996)	27
Killer Whale [ou]	CA/OR/WA	*Orcinus orca*	600 (1996)	1.2
Killer Whale or False Killer Whale [or]	Southern Resident Stock	*Pseudoorca crassidens*	96 (1996)	0
Bottlenose dolphin [c]	California coastal	*Tursiops truncatus*	134 (1996)	0
Common dolphin, long-beaked and Common dolphin, short-beaked [c]	California and CA/OR/WA, respectively	*Delphinus delphis*	27832 (1996) and 318446 (1996), respectively	14 and 231, respectively
Pacific White-sided dolphin [c]	CA/OR/WA	*Lagenorhynchus obliquidens*	10059 (1996)	17
Northern Right-whale dolphin [s]	CA/OR/WA	*Lissodelphis borealis*	10059 (1996)	38

Striped dolphin [or]	CA/OR/WA	*Stenella coeruleoalba*	17943 (1996)	1.2
Spotted dolphin [r]	CA/OR/WA	*S. graffmani*	Unknown	Unknown
Rough-toothed dolphin [r]	CA/OR/WA	*Steno bredanensis*	Unknown	Unknown
Dall's porpoise [c]	CA/OR/WA	*Phocoenoides dalli*	81061 (1996)	23
Harbor porpoise [r]	Central California	*Phocoena phocoena*	3341 (1996)	14

Sources: Woodhouse, C.D. 1988. Marine Mammal Assessment for the Waters Offshore Point Arguello, California in Relation to the SLC-7 Project at Vandenberg Air Force Base. Technical Report to Environmental Solutions, Inc. July; Barlow, J., P.S. Hill, K.A. Forney, and D.P. DeMaster. 1998. U.S. Pacific Marine Mammal Stock Assessments: 1998. US Department of Commerce. NOAA-TM-NMFS-SWFSC-258. December; Barlow, J. 1997. Preliminary Estimates of Cetacean Abundance off California, Oregon, and Washington based on a 1996 ship survey and comparisons of passing and closing modes. Southwest Fisheries Science Center Administrative Report. LJ-97-11; Julian, F. 1997. Cetacean mortality in California gill net fisheries: preliminary estimates for 1996. International Whaling Commission. Working Paper SC/49/SM2; Bonnell, M.L. and M.D. Dailey. 1993. Marine Mammals. In M.D. Dailey et al. (eds.). Ecology of the Southern California Bight. Pp. 604-681. University of California Press.

Notes:

*Census estimates for cetaceans are not as reliable and valid as population estimates of resident marine mammals. Marine mammals are highly migratory and population centers may shift on large spatial scales (>100 km) over small time scales (days or weeks) (Bonnell and Dailey 1993). Migrating cetaceans pursue short-lived resources of food, such as patches of small planktonic crustaceans or spawning fish and squid.

** Methods of distinguishing Mesoplodont beaked whales have not been adequately developed, so the management unit is defined to include all Mesoplodon stocks in this region, in accordance to Barlow et al. 1998).
r = Rare and uncommon visitor to the SCB. Represented by few sightings.
+ = Most of the world's population passes through the SCB in winter and spring.
m = Migratory Population.
c = Common year-round resident.
o = Occasional visitor and uncommon.
s = Seasonal resident population.

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